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Exploring Collaboration Patterns among Global Software Development Teams

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Abstract

This study examines communication behaviors in global software student teams. The authors of the paper characterize the types of communication behaviors that occur when student teams are engaged in a software development project. The authors present findings from a one-semester study that examined factors contributing to successful distributed programming interactions among students enrolled at the University of Atilim (Turkey), Universidad Tecnológica de Panamá, University of North Texas, and Middlesex University (UK). Using content and cluster analyses techniques, we identified distinct patterns of collaboration and examined how these patterns were associated with task, culture, GPA, and performance of collaborative teams. Our results suggest that communication patterns among global software learners may be related to task type, culture and GPA. It is hoped that these findings will lead to the development of new strategies for improving communication among global software teams.

1. Introduction

Advances in technology and changes within many organizations have led to an increased interest in people who possess effective teamwork skills. Most modern businesses require their workers to establish collaborative relationships to achieve organizational goals. As firms become more global, collaboration is becoming increasingly important. In order to function more effectively, workers must develop skills that help them communicate and collaborate across distances,

often with no face-to-face interactions with members of their team [1].

The need for people with collaborative skills is also increasingly important within the information technology community. The Software Engineering Institute (SEI) has released several papers that talk about the importance of collaborative skills in the software engineering area. According to SEI, the U.S. software industry is being asked to develop larger software systems, more rapidly, with higher quality, and at lower cost. Therefore, SEI suggests that collaborative teams can be used to increase worker involvement, improve quality and productivity, as well as help flatten, downsize, and decentralize the organization. The team approach is also being applied to the development and maintenance of software [2].

As part of their mission to produce graduates who are flexible and have market ready skills, computer science and IT educators have recognized the value of teaching students how to work in groups. As part of this interest, universities have started to introduce courses that teach students how to develop software with students who may live in different time zones and countries. The importance of these courses cannot be overstated, particularly given the economic downturn that has occurred in the past several months. However, teaching students how to communicate within global software teams is not always easy; time zone differences often lead to uncomfortable communications and social exchanges that can often lead to a breakdown in trust and productivity. Given the various obstacles that confront virtual teams in industry, it is important to identify the communication behaviors that lead to more effective team performance

among global software development students so that educators can use this knowledge to teach their students how to have more successful collaborations.

In order to address this issue, we began a research project that is aimed at increasing the effectiveness of globally distributed learning teams, particularly student programming teams that are composed of individuals who have different cultures and who live in different time zones. One of the major goals of this project is to determine how to teach students to use new technology to communicate more effectively. The project involves researchers from Turkey, Panama, UK, and the US along with a group of industrial advisors from various software industries. The specific universities involved in the project are Middlesex University (MDX), Universidad Tecnológica de Panamá (UTP), University of North Texas (UNT), Middle East Technical University (METU), and Atilim University (AU). Each semester, students from the participating universities are placed into groups and asked to complete a software development project. The software projects are intended to more accurately reflect the time zone and cultural differences that are found in real-world software projects. Using various computer-supported collaborative tools, students learn how to coordinate the different software development tasks. Because the collaborative software logs all online activities, we are able to examine the different communication interactions to determine which specific behaviors lead to better performance. These particular analyses are designed to give us useful insights into the specific communication behaviors that affect distributed teams and to provide a basis for determining how to improve less successful collaborators.

Thus, this paper presents findings from a one-semester study that investigated factors that contribute to successful distributed programming interactions among students enrolled at Atilim University (Turkey), Universidad Tecnológica de Panamá, University of North Texas, and Middlesex University (UK). A total of 152 students from the four universities participated in two projects during spring 2008. The first project involved students from the US and UK, and the second project included students from the US, Turkey, and Panama. All teams communicated with each other using collaborative tools that supported real-time chat, forums, file-sharing, and wiki entries. However, after an initial online meeting, the majority of the groups communicated using only asynchronous tools. Thus, this particular study focuses on characterizing asynchronous communication behaviors that occur within a global software development learning environment, and how these behaviors may relate to different software tasks and team performance.

2. Literature Review

Several researchers have examined factors that lead to better group performance [28]. For example, Dillenbourg and Schneider [3] report that some of the more important factors for effective collaborative learning are group composition, task features and communication media. The authors explain that group composition includes variables such as age, grade levels of the participants, the size of the group, and the individual differences among group members. Task features refer to elements of the task itself. Dillenbourg and Schneider argue that there are some tasks that cannot be shared, requiring students to work on their own, while there are other tasks that can actually provide students with a positive shared experiences.

According to Dillenbourg and Schneider, a third important factor for collaborative learning is communication media. Collaborations can often fail because the media selected for the communication is inadequate, regardless of the composition of the teams or the appropriateness of the task [3]. Thus, it appears that the combination of communication and technology is one of the factors that can impact group performance

It is well recognized that communication also plays an important part in the success of global software teams in both industry and academics [4]. Numerous articles confirm the importance of effective communication in virtual teams [5, 6, 7, 8]. As one author reported [9], software teams with the most technical problems and least amount of leadership also have the lowest number of e-mail messages and volume of communications per team member. Yet a virtual environment presents numerous challenges for effective communication. Problems such as time delays, lack of a common frame of reference, differences in languages and language understanding make frequent and uninterrupted communication among remote teams difficult [10]. Moreover, nonverbal communication, which is an important component of team communication, is usually missing in virtual teams because our current technology is able to convey only a limited set of perceptual cues [11].

Communication also plays an important part in the success (or failure) of distributed learning teams. There are numerous studies that support the idea that interactions with both the instructor and other students are essential elements in distributed learning courses [12, 13, 14]. Garrison, Anderson, and Archer [15] describe the importance of creating a “virtual community of inquiry,” which consists of establishing mechanisms that allow learners to construct knowledge by analyzing the subject matter, questioning, and thinking. It has also been argued that a student who

engages in a higher extent (or greater amount) of communication will transfer more knowledge to his/her remote team members and, thus, increase team performance. As a result, a teacher often makes a judgement about a student's performance by looking at the number of chats or notes that he/she posted. Studies have also tried to look at online activities such as the number of messages [18], mean number of words [19], thread-length [18], and social network analysis [20] in order to measure the extent of student collaboration. While these types of counts help establish a student's activity level, they do not necessarily lead to a judgement about the quality of those individual activities.

It is now widely believed that reporting on the quantity of communication activities alone is not sufficient to understand group collaboration [21]. To understand the true effects of a particular communication activity, recent research has suggested that we examine the communication patterns in online interactions to determine how such patterns can affect the performance of the group [22, 23]. A communication pattern is generally established through the use of a particular coding scheme that characterizes an online interaction. For example, Walther describes communication patterns in terms of personal, interpersonal and hyper-personal behaviors, whereas other researchers describe communication patterns in terms of different functions such as explaining, reporting, discussing [24]. Still other educators have developed coding schemes that describe students' critical thinking skills, which are then used to measure the quantity of such activities within an online discussion [25, 26]. Coding schemes have also been developed for determining the overall meanings of a set of postings, and how these different meanings are transferred to a participant's ability to perform other related tasks [27, 28, 29]. Finally, researchers such as Jeong [30] and Bakeman [30] have looked at students' discussion as a whole in an attempt to learn about the relationships and transitions that occur within and among different interactions. Thus, there is a wide variety of different coding schemes, each designed to answer a specific question posed by the various author(s) [31].

One of the major questions that educators within the computer science and IT communities have asked is: How does the communication that occurs within a group project affect the overall performance of the team? This question is probably even more relevant to an understanding of global software learning teams, given that computer-mediated communication is the only way that members can have any social interaction [16] or knowledge transfer [17]. Much of our knowledge about how global groups communicate with

one another has been derived from industry or research about offshore communities, which may not accurately reflect the way students actually work. There is a growing need to discover the real communication behaviors that occur within these student projects so that we can use this knowledge to improve both the teaching and learning of teamwork skills.

3. Methodology

3.1. Overall design of study

The data that was used in this study was obtained from two global software development projects conducted in spring 2008. Students in the United States and the United Kingdom were teamed for one of the projects, which occurred between February 18 - April 18, and students from Turkey, Panama, and the US were grouped together for the second project, which took place between April 14 and May 3.

Before each project, researchers met to determine the overall requirements of the programming assignments, as well as how the different projects would be integrated into existing curriculum. Thus, the actual programming assignments tended to vary according to the skill levels of the participants and the subject matter for the courses. The two learning objectives that guided the development of the group exercises were: (1) students should learn about the challenges and opportunities of asynchronous collaboration within a virtual setting, and (2) students should gain experience working with people from a different country or culture. A more detailed description of the two projects is available in Section 3.4.

The participating faculty included the exercise as part of their regularly scheduled class. After a brief training period, students were introduced to their team members (either through a teleconference or synchronous chat), and provided information about the task as well as management of the teams. Students enrolled in these courses received between 10-15 percent credits as part of their overall course grade for completing the project. To further motivate team participation, students were also given prizes for their participation and performance.

All student teams were asked to use only designated collaborative software to communicate with one another. The various collaborative software systems that were used in this project support asynchronous communication tools such as forums, emails, file sharing etc., as well as synchronous communication tools such as chat. Since these systems have record

keeping capabilities, we were able to capture the communication behaviors for each team.

3.2. Subjects

The subjects for the study consisted of 152 students from four universities. Table 1 summarizes some of the demographic information about the student participants. Table 1 shows that there were 35 females and 117 males who participated in the projects. Of the total number of students, 125 were undergraduate and 27 were graduate students. All of the participating students were currently enrolled in a computer science or information technology department.

Table 1. Demographics of subjects

University	# of students	Level	Male	Female
AU	32	BS	18	14
MDX	36	BS	24	12
PTU	26	BS	21	5
UNT	27	MS	41	17
	31	BS		

AU: Atilim University, Turkey

MDX: Middlesex University, UK

PTU: Universidad Tecnológica de Panamá, Panama

UNT: University of North Texas, US

The participating students at Atilim University were enrolled in a Java programming course. The team members at Middlesex University were all first-year students enrolled in a Business Information Systems Course. The students from Panama were not enrolled in a single course, but were recruited from several different project-oriented courses, all of which were fairly advanced. The graduate students from US were enrolled in either a Human Computer Interface course or a Database course.

The 152 participants were between the ages of 19-25 years old. The average grade point average (GPA) for students in Panama and Turkey was around 2.0, while US students averaged 3.6 (which would be expected given that some of these participants were graduate students). The UK students receive marks instead of grades, so their averages were translated into a GPA that was around 2.5.

According to the survey responses, 70 % of the students stated that they had previously worked in a collaborative team, and only 1% of the students stated that they had never worked on a team project.

The Turkey-based students were eight hours ahead of the US-based students and seven hours ahead of the Panama-based students. The UK-based students were one hour ahead of the Turkey-based students.

3.3. Collaborative teams

As stated in Section 3.1, US and UK students were grouped together for one of the global software development projects, and US, Turkish, and Panamanian students were grouped together for a second project. UK-US project consisted of 10 teams of students, with approximately 3 co-located members and 3 dispersed members in each group (for a total of 6 students in each group).

The US-Turkey-Panama project also had 10 teams of students, with approximately 3 students in each group from each of three universities (for a total of 9 team members in each group).

The students in each project team were randomly assigned to their teams. The students were not allowed to change their teams during the project. The language for communication within the project teams was English.

3.4. Collaborative tasks

There were two separate collaborative exercises designed for two separate global software development projects. These exercises were determined by the curriculum of the courses that were involved in the study. For example, since the student teams in the US-UK project were enrolled in either a Database or IT course, they were given an assignment to design, create and query a database that could maintain a fleet of rental cars. Students were expected to produce the E-R diagram and test queries for the database as well as a final working system. The students were also responsible for completing several reports.

The second collaborative task was given to students enrolled in interface design and programming courses. So this programming assignment consisted of a mid-size software development project involving a fictitious university that was requesting software to create groups (such as the kind that were created for this project). The input for this second application was a set of criteria (as specified by the user) and a file containing a list of names of students who were enrolled in a course. The output for the project was a list of the groups and the students assigned to those groups.

The participants in both projects were asked to act as members of a global software development team, which was given the responsibility of developing the design or code for a particular project. Participants were provided with a summary of the particular case. The summary document also included background information about the project and suggested assignments for the team members in each country.

Both assignments required students to deliver both design and code as part of their final product.

3.5. Data collection procedure

A combination of quantitative and qualitative research methods was employed in this study, including surveys and content analysis. A survey was administered to team members both at the beginning and the end of the projects. These surveys were designed to collect demographic data about each student participant.

All teams were instructed to use asynchronous tools to communicate with each other. The US-UK pilot project used OAS!S+, a Virtual Learning Environment that is created through the customization of the WebCT Vista / Blackboard platform. This computer managed instructional software supports asynchronous communications such as forums, emails, file sharing etc., and synchronous communication such as chat. The US-Turkey-Panama teams used an open source platform learning management system called Online Learning and Training (OLAT). This tool also supports forums, chats, file sharing, and emails.

The US-UK online communication consisted of the group interaction data obtained through the OAS!S+ system, which automatically records posting and chat information. Data from the US-Panama-Turkey project was obtained from the OLAT system directly, and from programs that were developed to augment OLAT's data collection capabilities. The recorded data included information about each chat, forum posting, file upload, and wiki entry, along with the date, time, and author of each online activity.

A team's performance was evaluated by averaging the individual grades on each of the assignments. Projects were evaluated based on four criteria – accuracy, efficiency, thoroughness, and style. A design or a program was considered accurate if it satisfied the user's functional requirements and contained no errors. A project's efficiency score was evaluated by examining the number of program modules. A program's thoroughness was scored on whether the design or program included all the necessary elements. Finally, good programming style was judged by the examining the style (e.g., variable naming conventions, indentation, etc.) of the code. Researchers from each university graded their own student projects as well as those from the other participating countries. A mean grade for the project was then assigned to each student.

3.6. Data analysis procedure

Data analysis generally involves the generation of data from the events or objects under investigation, the collection and maintenance of that data in records, and the transformation of the data into useful information. In this study, the data consisted of posts to on-line discussions and the students' grades on the projects.

In order to explore the nature of team interaction in global software learning teams, each group's chat/forum discussion was coded to determine the overall number of communication behaviors devoted to planning, contributing, seeking input, reflection, and socializing. Since the research activities discussed in this paper were aimed at trying to characterize the group dynamics within distributed software teams, the researchers chose a coding scheme that tries to characterize student group's collaborative behaviors [32]. Curtis and Lawson [32] identify nine different behaviors (described in Johnson & Johnson [33]) as being supportive of the collaborative process, and then developed a coding schema that could be used to categorize different utterances in on-line collaboration.

The final Curtis and Lawson coding scheme consists of 15 separate communication behaviors that are categorized into 5 behavior categories. The behavior categories and the individual behaviors are given in the Table 2. The authors used this schema to determine the extent to which various components of collaborative learning can be used to describe the on-line interactions of students placed in learning groups.

Table 2. Coding scheme and communication behavior Categories [30, p.8]

Behavior Categories	Behaviors
Planning	Group Skills, GS
	Organizing work, OW
	Initiating Activities, IA
Contributing	Help Giving, HeG
	Feedback Giving, FBG
	Exchanging Resources and Information, RI
	Sharing Knowledge, SK
	Challenging others, Ch
	Explaining or elaborating, Ex
	Help Seeking, HeS
Seeking Input	Feedback Seeking, FBS
	Advocating Effort, Ef
	Monitoring Group Effort, ME
Reflection/Monitoring	Reflecting on medium, RM
Social Interaction	Social Interaction, SI

The original Curtis/Lawson [32] coding scheme was based on an exploratory study that examined online discussions of students who were engaged in a

collaborative task. The authors examined the log files of interactions that occurred while using an online discussion management system. The content of the students' email messages and forum discussions were coded for evidence of collaboration among group members. Curtis and Lawson then derived the final coding system from an analysis of the students' messages. Curtis and Lawson classified statements that related to organizing work, initiating activities, and group skills under a *planning* category. Communications related to the utterances such as giving help, providing feedback, exchanging resources, sharing knowledge, challenging others or explaining one's position were classified in the *contributing* category. Other collaborative behaviors were also noted such as *seeking input* and *reflection*. Conversations about social matters that were unrelated to the group task were placed in the *social interaction* category.

The authors of this paper used the Curtis Lawson categories to identify different types of group behavior in the online student interactions that took place in both projects. Codes were assigned to utterances that indicated collaboration. Duplicate codes were assigned whenever an utterance indicated multiple collaborative behaviors.

After coding the different data, the authors performed a cluster analysis to identify the collaboration patterns in project teams from the different universities and cultures. The primary purpose of cluster analysis is to group objects of similar kind into respective categories or classifications [35]. The groups or clusters that result from this classification process identify characteristics that distinguish the cases in different segments. Since the primary objective of this particular study was to identify distinct groups of global software learners with similar communication behaviors, we used cluster analysis to show which groups had similar communication patterns.

The clustering variables used in this study were each group's number of interactions devoted to the five interaction behaviors. Based on a review of clustering techniques, we chose a hybrid clustering method to identify the different groups. The hybrid clustering technique uses two methods namely k-means and Ward's hierarchical agglomerative clustering. After obtaining the centers (or centroids) of each cluster using Ward's method [34], the resulting centroids are then used as the initial seed points for the nonhierarchical k-means cluster analysis.

4. Findings

4.1. Overview of communication behaviors in groups

Across all the twenty global software development-learning projects teams, a total of 1985 communication incidents were analyzed. If the behavior was not present in a communication incident, it was assigned a score of 0; conversely, if a communication behavior(s) was present in a posting, then it was assigned the code or codes for that behavior. As a reliability check, a second coder analyzed the same discussions. Inter-rater reliability between coders for the interactions behaviors was acceptable (.84)

Table 3 summarizes the resulting *proportions* of the collaborative behaviors that occurred in teams from each university.

Table 3. Proportion of collaborative behaviors in each category for each university

Uni.	Planning	Contributing	Seeking Input	Reflection/Monitoring	Social Interaction
AU	0.02	0.01	0.01	0.00	0.01
PTU	0.04	0.06	0.03	0.01	0.01
UNT	0.16	0.22	0.10	0.04	0.04
MDX	0.04	0.08	0.10	0.01	0.01
Totals	0.26	0.38	0.24	0.06	0.06

The analysis of utterances entered by groups in both projects indicates that the highest proportion of communication activities relate to *contributing behaviors*. Although not shown in Table 3, the contributing sub-categories of *exchanging resources* and *feedback giving* have the highest proportions of contributing sub-category behaviors.

Table 3 shows that all student groups tend to have an equal proportion of *planning* and *seeking input* behaviors. The behaviors associated with *feedback seeking*, *organizing work* and *group skills* have the highest proportions in the planning and seeking input areas. Finally, communication behaviors associated with *reflection and monitoring* and *social interaction* have the lowest proportions, accounting for only 3-4% of all coded behaviors.

The comparison of the communication behaviors for each project is presented in Figure 1. The UK-US project is labeled 1," whereas the UK-UNT-Turkey project is labeled 2.

As seen in Figure 1, the teams working in Project 2 spent an equal proportion doing all of the collaborative behaviors. Project 2 teams spent an equal proportion of their time spent *planning* and *contributing*. Project 1 teams spent most of their time *contributing* and

seeking feedback categories. *Feedback seeking, feedback giving* and *exchanging resources and information* were the dominant communication behaviors in Project 1.

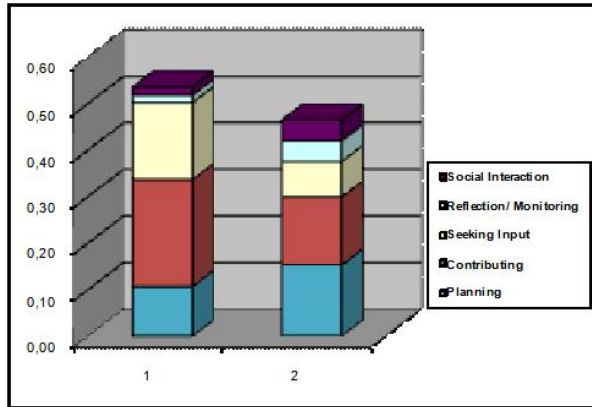


Figure 1. Proportions of collaborative behaviors in Projects 1 and 2

4.2. Collaboration patterns by cluster

The cluster analysis of the agglomeration schedule generated from Ward's method suggests a five-cluster solution. Figures 2, 3 and 4 show some interesting communication patterns as a result of the cluster analysis. Figure 2 presents a graphical view of the number teams in each cluster as well as the project that those teams were assigned. As seen in Figure 2, the clustering process yielded groupings that appear to distinguish between the communications behaviors that occurred in both Projects. For example, cluster 2 consists of only teams that participated on Project 1, while clusters 4 and 5 contain only the teams that worked in Project 2. The other two clusters, 1 and 3, include teams from both Projects.

Figure 3 shows the number of different communication behaviors that occurred in each of the clusters. Cluster 4 had the largest number of communication activities, and cluster 5 had the fewest. Clusters 1 and 2 had a similar number of total communication exchanges. While this information is interesting (e.g., cluster 4 seems to have “out-communicated” all other groups), it is not particularly useful for comparing the communication behaviors among the five clusters. Therefore, we also computed the proportion of postings devoted to each of the five communication behaviors. Figure 4 represents the different behavioral categories as proportions of postings devoted to the five interaction behaviors for each cluster. Since this figure illustrates proportions,

high scores on one interaction behavior are associated with lower scores on the others. For example, Figure 4 shows that the communication behaviors of students in cluster 4 were evenly distributed among the four behavior categories of planning, contributing, seeking and reflection, with less time spent socializing, whereas teams in cluster 5 spent almost all their time socializing.

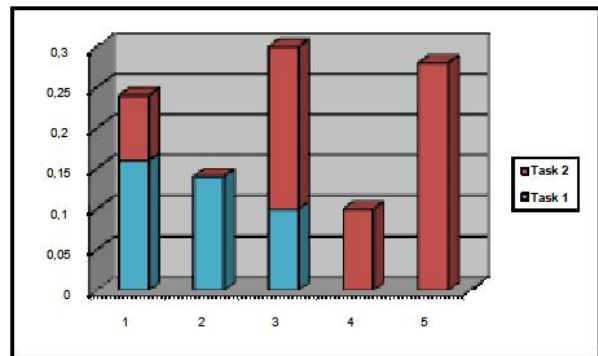


Figure 2. Number of teams in each cluster by project (1 & 2)

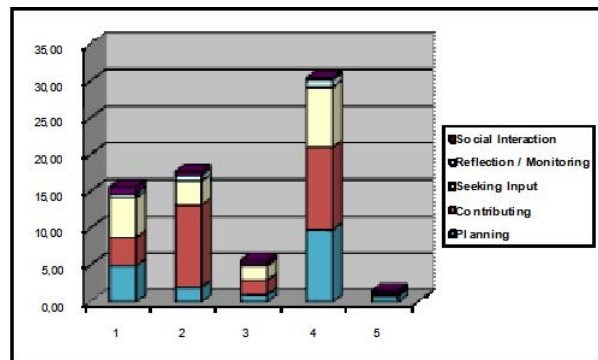


Figure 3. Number of communication behaviors for each cluster

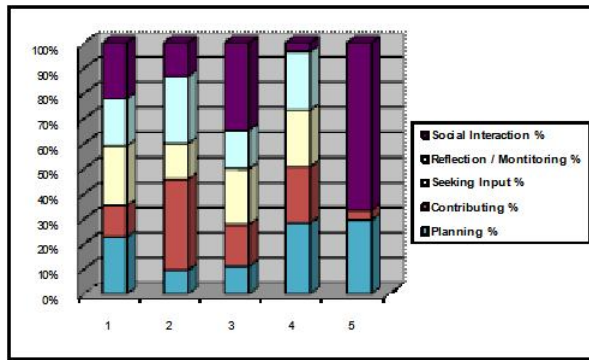


Figure 4. Proportion of communication behaviors for each cluster

As indicated in Figures 2 and 3, teams in cluster 4 spent an equal proportion of their time contributing, seeking input, planning and reflecting. Relative to the other three clusters, clusters 2 and 4 spent a similar proportion of their time reflecting, whereas cluster 2 seems to have spent much less time planning and more time exercising contributing behaviors. In contrast to all the other teams, Cluster 5 spent almost all their time on social interactions, and very little time seeking input, reflecting or contributing,

4.4. Clusters and team performance

Having associated the clusters with specific patterns of communication behaviors, we then examined the relationship between the clusters and team performance. As previously mentioned, team performance was defined as an average of the grades on the project. A one-way ANOVA was used to analyze the performance data. Although cluster 4 obviously outperformed the other four clusters, the performance was not statistically significant (Table 4).

Table 4. ANOVA of performance by cluster

Clusters	1	2	3	4	5
N	36	16	39	14	38
Mean	60.56	51.18	62.05	74.29	61.95
Std. Dev.	22.89	31.8	34.88	36.31	31.88

We also looked at the relationship between students' GPA and a cluster's communication behaviors (Table 5). A one-way ANOVA, followed by a Scheffe test indicated that there was a significant relationship between GPA and communication behaviors. The results of the post-hoc Scheffe showed that there were mean differences between cluster 1 and clusters 2

(3.70, $p < .05$) and 4 (4.96, $p < .05$). No other significant differences among the clusters and GPA were found. This information, along with the communication patterns and performance data, seems to suggest that groups, teams with high GPAs (e.g., cluster 2) also need to know how to balance their time among different tasks in order to be successful.

Table 5. ANOVA GPA by cluster

Clusters	1	2	3	4	5
GPA Mean	2.45	3.23	2.99	3.29	3.05
Std.Dev.	0.91	0.61	0.8	0.54	0.8

4.5. Culture

Finally, we examined the relationship between culture and communication behaviors, as represented by the five clusters. Table 6 shows the number of students in each cluster by culture. A comparison of the clusters by cultural groups indicates that culture may have some relationship to the type of communication patterns that occur within a group. Clusters 3 and 4 appear to have the most evenly distributed cultural groups, whereas cluster 2 is composed of only US and UK students. As previously mentioned, this particular cluster consists of only those students who participated on Project 1, which may have been why these students are in this cluster. Similarly, cluster 5 consists of only those students who worked on Project 2. Although the chi-square test performed on this data indicates that there is a relationship between cultural groups and communication behaviors was significant ($\chi^2 = 47.1$, $p < .01$), that relationship may be more the result of task type rather than culture.

Table 6. ANOVA Culture by cluster

	Clusters				
	1	2	3	4	5
US	11	9	10	3	19
Turkey	9	0	11	3	9
UK	17	8	7	3	0
Panama	0	0	11	5	10

5. Conclusion

Learning how to work in global software development student teams is challenging and sometimes even difficult. Team members need to learn how to not only design, implement, and validate

software systems, but they must learn how to work in culturally diverse work teams, manage time, express ideas, and communicate with other people. Students must also learn how to use collaborative technologies such as teleconferencing, video conferencing, e-mail, voice mail, and groupware applications to communicate with team members who may be located in other cities and even countries.

The study reported in this paper examines communication behaviors in global software development student teams. The authors of this paper characterize the types of communication behaviors that occur when student teams are engaged in a software development project. The paper also reports on the results of a one-semester study that investigated factors contributing to successful distributed programming interactions among students enrolled at University of Atılım (Turkey), Universidad Tecnológica de Panamá, University of North Texas, and Middlesex University (UK).

Our results suggest that communication patterns among global software development learners are related to task type, culture, and GPA. The findings show that that task type seems to be one of the most important factors in promoting collaboration among the team members. Although there were no significant differences in performance among the 5 clusters, cluster 4 clearly outperformed all other groups. This higher performing cluster had more communication behaviors than any other cluster, and their communication activities were more evenly distributed among the different types of communication activities. We hope to continue to look at students' patterns of communication in hopes of discovering which types of behavior lead to better performance.

Finally, it should be remembered that these findings are limited to a relatively small, one-semester-long, student software development project. Future research will try to establish the external validity of the study and determine if its results can be generalized to other global software learning projects. This study reports on only the use of asynchronous technology, and its impact on team performance. Complex media is becoming increasingly more commonplace in the classroom, and students are starting to use this media to work together on team projects. Research about the relationships between the use of complex media and team performance should help us better understand the group dynamics that occur within global software student teams and how this interaction can help us better understand the software engineering process.

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